Satellite observations and modelling of hydrogen cyanide: The Indonesia 2015 peat fire season case study

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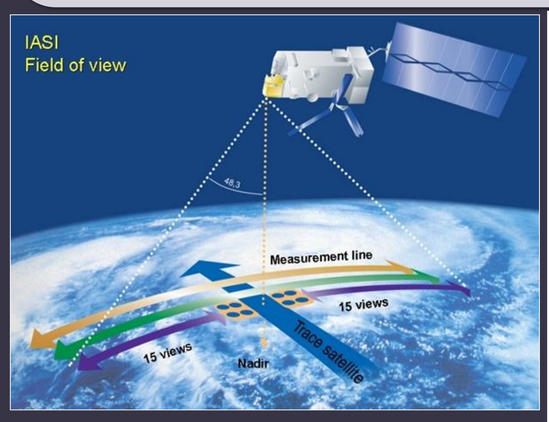
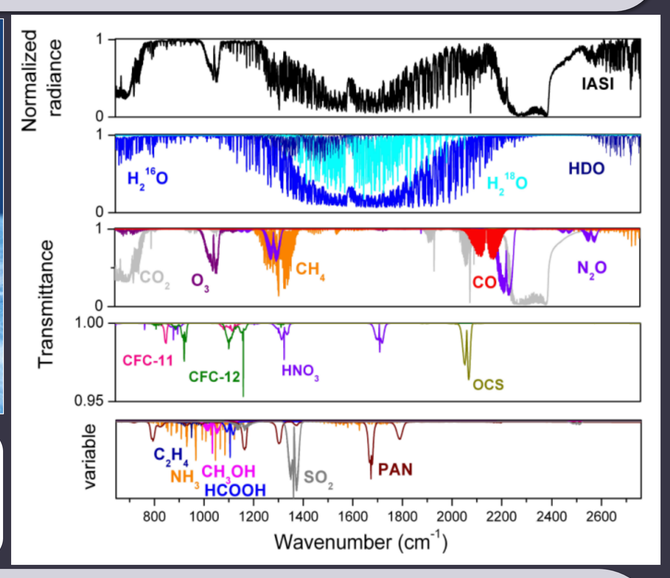
1. Introduction

- Wildfires in Indonesia are seasonal events regulated mainly by the agricultural practice of burning old vegetation for land clearing in order to prepare the soil for the new planting season.
- El Niño exacerbates the typical extreme weather conditions of the Indonesian wildfire season, making burning events difficult to control, as they were towards the end of 2015.
- Indonesian land contains a high percentage of peat, a carbon-rich type of soil, which emits a large amount of hydrogen cyanide (HCN) when burning.
- For this reason, HCN is a good atmospheric tracer for peat fires.

2. The Infrared Atmospheric Sounding Instrument (IASI)

- IASI is a Michelson Interferometer onboard METOP measuring atmospheric spectra in the TIR range – 645 to 2760 cm^{-1} (15.5 to 3.62 µm)
- Data have a spectral sampling of 0.25 cm^{-1} and a spectral resolution of 0.5 cm^{-1}
- 14 orbits per day in a polar sun-synchronous orbit, local time ~09:30 (descending orbit)
- Global daily coverage due to large 2200 km swath width



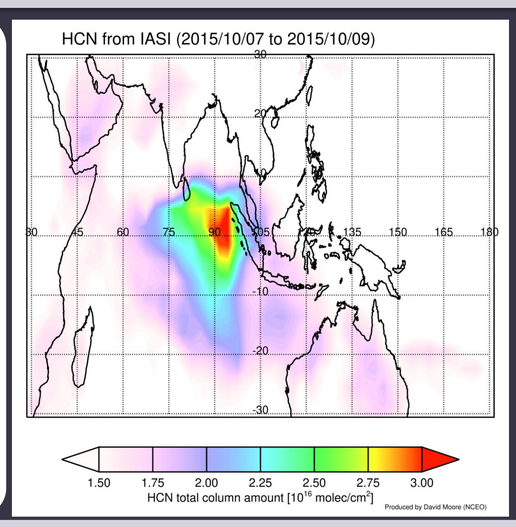


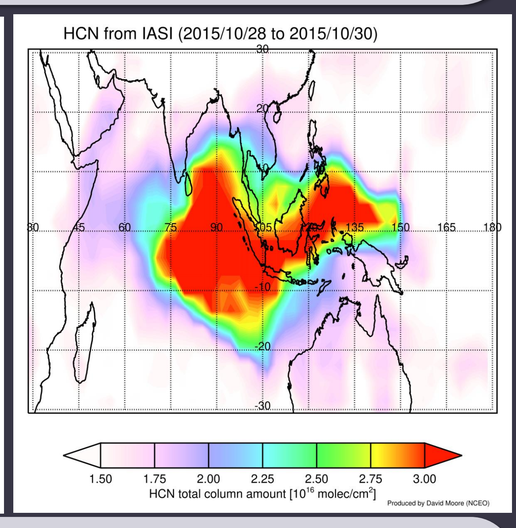
(Above) Viewing geometry of the IASI instrument. (Right). An example of an IASI spectrum alongside the major absorption bands of a number of important trace gases in the atmosphere.

3. ULIRS

The University of Leicester IASI retrieval scheme (ULIRS) is a full optimal estimation method used to perform global partial/total column retrievals from IASI spectra. It provides each measurement with errors and sensitivity profiles. ULIRS uses the Oxford Reference Forward Model (RFM) as forward model to simulate TOA radiances in order to determine both HCN total columns and concentration profiles. The algorithm uses 8 selected channels to determine the HCN spectral features.

(Right) Three-day average distribution of HCN from IASI retrieved by ULIRS during the 2015 wildfire season in Indonesia. The two plots from the beginning and end of October clearly show the HCN plume coming from Indonesia.

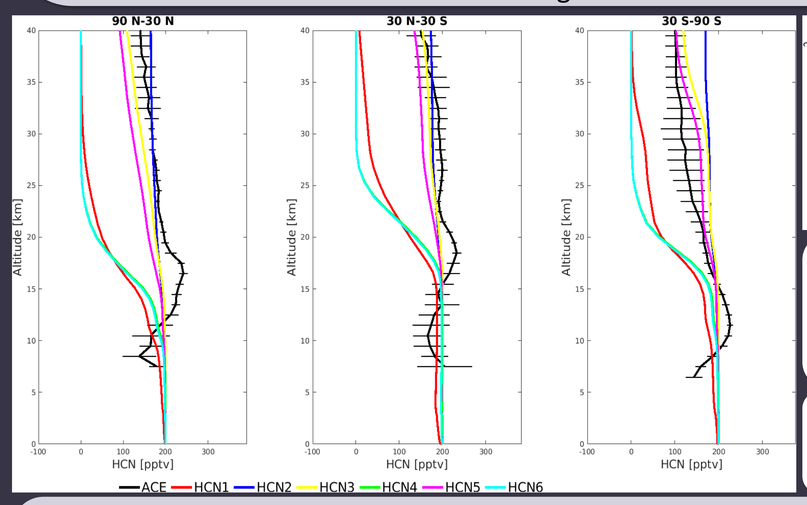


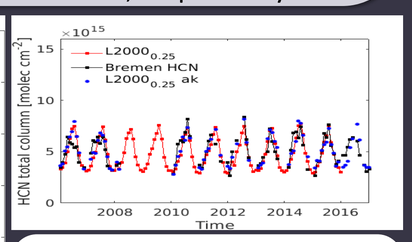


4. TOMCAT

A version of TOMCAT 3-D global CTM is used to simulate atmospheric HCN chemistry. The model is run at a spatial resolution of $2.8° \times 2.8°$ on a 60-level vertical grid. The model uses surface HCN biomass burning emissions from GFED:

- 12 tracers were developed to reproduce the processes driving HCN variability: oxidation by OH (two reaction rates), oxidation by O(^{1}D) and photolysis in stratosphere and the ocean sink at the surface (two schemes from *Li et al (2000, 2003)*
- Stratospheric reduction mechanisms and ocean sink are validated using ACE-FTS satellite observations and NDACC FTIR ground-based measurements, respectively

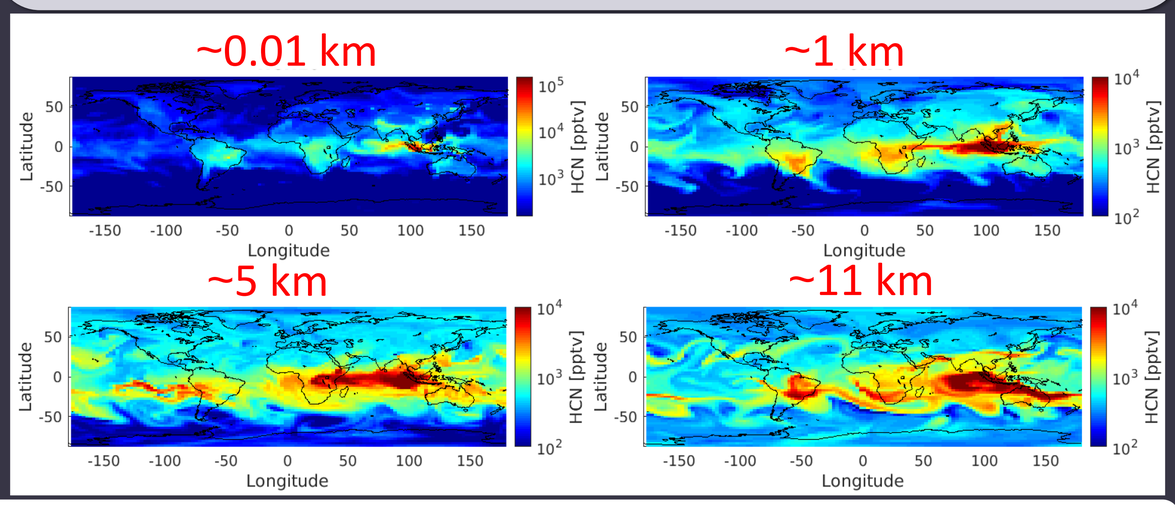




(Above) HCN total column time series measured and modelled with scaled Li (2003) ocean uptake applying the FTIR instrument AKs at Bremen NDACC station.

5. TOMCAT: Indonesia 2015 wildfire season

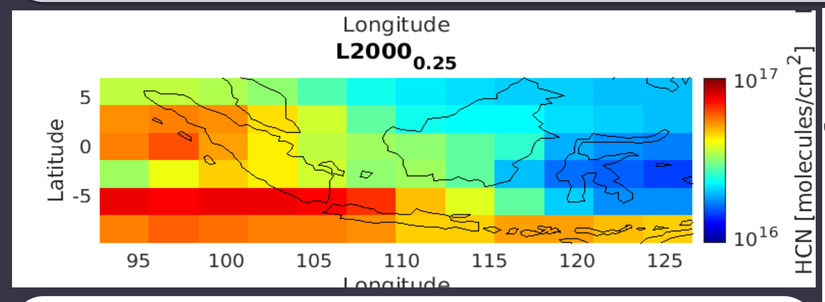
The TOMCAT model is used to investigate the HCN emissions during the Indonesia 2015 wildfire season through the troposphere where the wildfires emissions are mainly concentrated.
The model is able to reproduce the HCN plume distribution on different tropospheric levels showing the main emission peak about two weeks in advance.



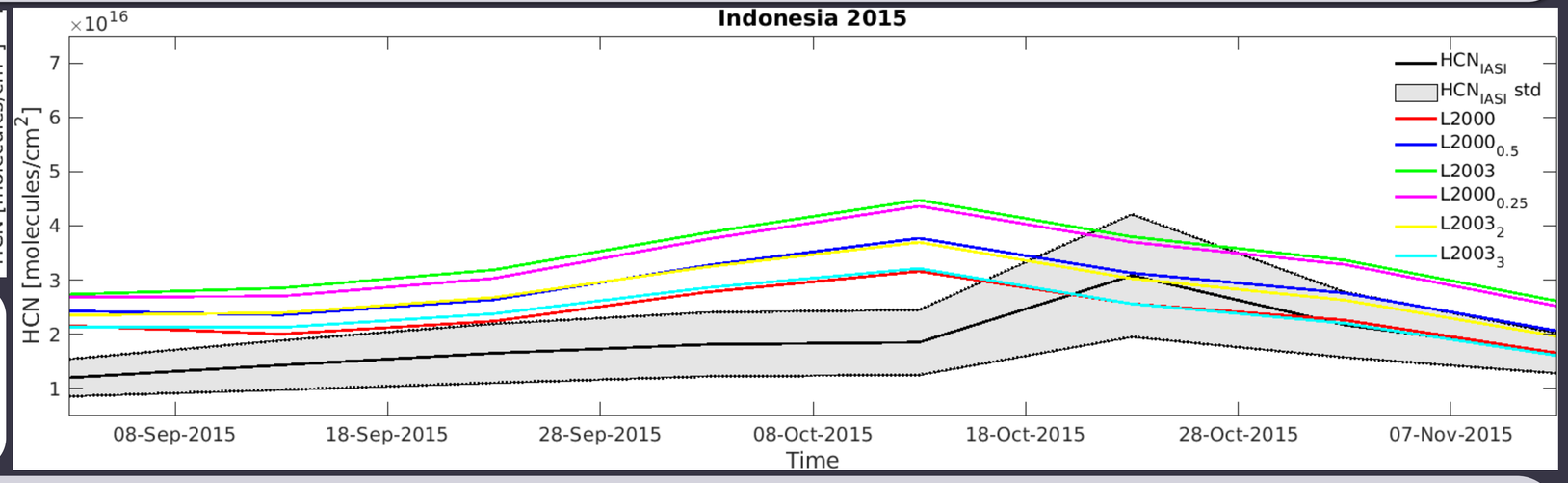
(Left) Average September 2009 HCN profiles modelled by TOMCAT compared with the profiles measured by ACE-FTS with 1 standard deviation for three 60 degree latitude bands. The HCN5 tracer which includes the OH and O(^{1}D) loss mechanisms shows the best agreement with measured profiles. (Above) Simulated global distributions of HCN for tracer $L2000_{0.25}$ on 18 October at different altitude showing the HCN plume through the troposphere.

6. TOMCAT-IASI comparison

The model data are smoothed with the IASI averaging kernels (AKs) to account for the different instrument vertical resolution. To take into account the different spatial resolution, the single pixel profiles of the model are smoothed using the AKs of all the IASI profiles falling within the pixel, the total column for each pixel is then obtained averaging the total column of all the smoothed profiles. The model averaged total column time series over Indonesia during the period September-November 2015 are compared with the total column time series measured by IASI.



(Above) Simulated distributions of HCN total column over Indonesia region for tracer $L2000_{0.25}$ on 8 October after the application of IASI averaging kernels. (Right) Averaged HCN total column time series measured by IASI with a standard deviation error over Indonesia during the 2015 wildfire season compared with the averaged total column modelled by TOMCAT over the same box for a series of 6 tracers with different HCN ocean sink treatments.



7. Results and future steps

- Using ACE-FTS profiles we found that the reaction with O(^{1}D) dominates HCN loss in the mid-upper stratosphere and using NDACC ground-based measurements we establish the need to scale the *Li et al (2000, 2003)* ocean uptake schemes to get reasonable agreement with measurements
- The TOMCAT model is able to reproduce the vertical distribution of HCN over Indonesia in the 2015 wildfire season
- The comparison of TOMCAT averaged total column timeseries with IASI measurements over Indonesia in Sept-Nov 2015 shows a good agreement on the HCN amount, but the main HCN peak in the model is about 10 days earlier than in the measurements. Further investigation are necessary to understand this discrepancy

References

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